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Laying the Foundations for True Cross-Domain Commonality: Why Is the Common Range Integrated Instrumentation System (CRIIS) Not the Answer for Test and Training Time-Space-Position Information?

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The vision of advancing to interdependent, interoperable, and, ultimately, common instrumentation for test and training has long been accepted as the utopian solution for accomplishing these two vital functions of defense preparedness. Whereas common challenges such as shrinking budgets, range encroachment, and diminishing frequency allocation would seem to compel these closely related domains to work together, cultural—not technological—barriers have prevented the U.S. Department of Defense from realizing this collaborative vision. The Test Resource Management Center, through its Central Test and Evaluation Investment Program, has initiated a standards-based approach to ensure that both the test and training communities have a common range platform from which to deliver time-space-position information (TSPI) suitable for both domains. The Common Range Integrated Instrumentation System (CRIIS) builds on the historical business model for common test and training range instrumentation, finally ensuring that the Department has a wholly government-owned solution ready to bridge the test and training interoperability gap. After years of closely analyzing the similarities of test and training TSPI systems, CRIIS contains all the right ingredients to deliver the most fundamental range capability using a common architecture…so why is it not the answer to both test and training domains?

Key words: Commonality; instrumentation; investment; range capability; test and training.

"If ever we are to achieve common test and training instrumentation, the time is now." For the past 20 years, countless studies, meetings, discussions, symposia, and papers have highlighted the benefits of achieving common test and training instrumentation. Numerous observers have cited that the most basic task of range instrumentation—providing time-space-position information (TSPI) on scenario participants—is so similar in both test and training domains that it would appear the obvious choice for a common solution. Discussions on the idea of interoperability—finding ways to share data among diverse systems—inevitably lead to the question, "Why do we have unique systems for each community?" Although the term "interdependence" has been used lately to describe the relationship between test and training systems, it neglects to address the obvious similarities between test and training TSPI systems that point to a shared solution. Commonality offers economies of scale that, alone, are worth the price of admission. The economic benefits address the primary fiscal challenges of both domains. For trainers, the test community offers a deeper investment pool for research and development (R&D) dollars; for testers, the training community brings an exponentially larger number of users to ensure production and sustainment beyond that which the test community alone could support.

But the real goals of common test and training systems transcend the economic benefits. Our world has progressed from an Industrial Age to an Information Age. Information technology is in many ways defining our generation. Warfighting has always evolved with the technological advances of the time, and this era is no exception. Information age warfare is

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characterized by the principle tenets of net-centricity, which exploits the key enabling functions of information technology and network technology, applied to the science of warfare. Four fundamental aspects of information/network technology must be considered in order to apply the technology in the most effective and efficient manner. First, the utility and effectiveness of information-enabled systems that work together to perform a collective task increase exponentially when connected over a common network. Second, these systems must be designed, tested, and operated as a networked System-of-Systems in light of the collective tasks. Third, networking systems and people together generally produces new capabilities that were impossible when the systems stood alone and requires modified operating approaches. Therefore, evaluating the performance of (testing) and operating (training) the System-of-Systems cannot be performed in a segregated manner. Fourth, no other technology moves at the pace of information/network technology. The serial approach to requirements validation (design, test, train, deliver) has proven inadequate, generally resulting in the delivery of obsolete capability that is not optimized for the joint net-centric battlespace.

What does this mean for the test and training domains? Both must accept that individual systems can no longer operate in isolation; that the measures for System-of-Systems performance are characterized as mission effectiveness, assessing information exchange end-to-end across mission threads; that the System-of-Systems includes equipment, people, and tactics, techniques, and procedures; that synchronized testing and training is required to optimize the rapid delivery of mission solutions; that synchronized testing and training requires a high degree of commonality in battlespace environments, infrastructure, and instrumentation; and, finally, that a partnership between the testers and trainers is the only way to achieve our collective objectives. Therefore, in addition to the fiscal advantages, the primary goals of common test and training are maximization of mission effectiveness through the application of net-centric technology and acceleration of the delivery of the ensuing warfighting capabilities with an agility that paces modern warfare.

In response, the acquisition community has identified net-readiness as a key performance parameter of every new major weapon system acquisition, leaving behind the era of stand-alone weapon systems testing. New weapons are designed at program initiation to function as a node in the joint net-centric battlespace, operating in most cases as both an information producer and an information consumer. These weapons rely upon a variety of off-board information sources, including command and control, sensors, and intelligence systems; these systems are fed through multiple information communication paths, chief of which is the Global Information Grid.

A weapon system unable to draw from and take advantage of the information-rich environment in which it will operate is critically handicapped. In recognition thereof, the Test Resource Management Center–led Joint Mission Environment Test Capability is laying the infrastructure to connect live, virtual, and constructive test participants from across the country and around the world. This construct aligns the test community with the U.S. Joint Forces Command Joint National Training Capability. With Joint National Training Capability, trainers already have begun to leverage live, virtual, and constructive capabilities at locations around the world to simultaneously enable more realistic training and avoid the expense and delays associated with transportation of all participants to a single geographic location. Consequently, a major opportunity has emerged for test and training interdependence, interoperability, and commonality. Testers can tap into this opportunity to render operational testing more realistic through traditional training venues, such as the red and blue flag exercises, while continuing to collect evaluation-quality weapon system data. Similarly, trainers can create scenarios to engage the most realistic threats available on traditional test ranges, creating a target-rich environment for warfighters to assess and hone tactics, techniques, and procedures.

The avenues for common exploitation of test and training resources are abundant. Two recent memoranda, jointly signed by leadership within the offices of the Director, Operational Test and Evaluation; Under Secretary Defense for Personnel and Readiness; and Under Secretary of Defense for Acquisition, Technology and Logistics noted the need for interdependent test and training capabilities, beginning with airborne instrumentation.

It is evident that today no insurmountable technical barriers exist to prevent interoperable, or even common, test and training systems. To better appreciate the issue in modern context, we will present a historical overview. Then, we will explore the technological arguments against commonality, demonstrating why they are largely overstated and how they can be resolved with current state-of-the-art technology. Finally, we will make a close examination of the Common Range Integrated Instrumentation System (CRIIS), illustrating how the standards-based approach greatly reduces any technological barriers that may have existed previously. The time for highly interoperable systems is here. If not us, who? If not now, when?

A historical perspective on TSPI: Are we condemned to repeat the past?

Ironically, to a large extent the airborne TSPI business began on common test and training footing. Tracking fast-moving targets across vast range space required a function called range control, keeping all participants where they needed to be for safety and evaluation purposes. The common solution for test and training was instrumentation radars, which still have utility for both communities today. However, one of the many drawbacks of radar is that accuracy degrades rapidly as a function of distance. To address radar deficiencies, a new tracking scheme, multilateration, was born. Two-way ranging signals from a number of survey-in fixed sites are used to provide accurate TSPI on range participants.

At this point test and training systems began to diverge. Multilateration systems are often terrain-dependent, driving them to different configurations, frequencies, power levels, etc. Then, in the early 1980s, researchers began to examine the application of a new technology to range-independent TSPI for air, land, and sea participants. This new technology, a space-borne multilateration system, while still in its infancy was dubbed the Global Positioning System (GPS). In 1985, the Office of the Secretary of Defense initiated the Advanced Range Data System (ARDS) program to develop GPS-based TSPI instrumentation for national test ranges. This instrumentation consists of a high-dynamic GPS set for aircraft and a low-dynamic GPS set for ships, land vehicles, and slow-flying aircraft (e.g., helicopters). The high-dynamic instrumentation was provided in two packages: an internal mount configuration and the more widely used "pod" configuration. Because this was applied primarily to U.S. fighter jets, a common pod interface based on the AIM-9 missile was used. The instrumentation package consisted of five key components: a GPS engine, an Inertial Measurement Unit (IMU), a two-way datalink, an onboard recorder, and an encryption system. GPS technology had rekindled the possibility of common test and training instrumentation—it nearly happened.

The original ARDS was developed by Interstate Electronics Corporation. In the mid-1990s, Metric Systems (now part of DRS Training and Control Systems) won the production contract, producing approximately 300 participant packages for the test ranges. Metric recognized an opportunity to market this capability in the training market and, subsequently, won a contract to provide the U.S. Air Forces in Europe Rangeless Instrumentation Training System (URITS), which enabled training missions to be conducted from Air Force bases in Europe where fixed ground infrastructures for range support were not readily available. Although not interoperable, the similarities between URITS and ARDS and the potential for interoperability are astounding; essentially, the systems are very similar except for some software modifications, the radio frequency front end, and the ground processing. Metric, however, did not stop there. At least two other systems, the P4 Refurbishment Contract system and the airborne segment of the Cubic Defense Applications' P5 Combat Training System (P5CTS), also are direct derivatives of ARDS. Today, P5CTS has become the mainstay training TSPI system in the Department of Defense. Because of a common architecture, the technologies incorporated in these products have been inserted back into the ARDS system as well; the latest version offers improved performance, maximizes commonality with training products, and includes foreign military sales and training variants.

This history lesson proves that test technology can be used by the training community. In the past, differences between training and testing equipment were driven by the need for greater precision in testing and the reluctance of the training community to pay for that precision. Advances in technology employed in ARDS and P5CTS pods demonstrate that the cost of precision has become affordable and that standardization between test and training equipment architecture results in savings for both production and logistics.

It is important to note that had the government predicted the success of ARDS for both test and training applications it easily could have synergized design properties to provide a *common* system to support either test or training with minimal hardware differences, making seamless test and training possible while significantly reducing R&D investment and life cycle support costs.

In light of this information we need to ask, "What can we in government leadership do differently now?" and "How can we keep history from repeating itself?" But first we talk about the technology.

Test and training are technologically very similar

The world of instrumentation has changed dramatically during the last 10 years. GPS has become the core technology for TSPI applications, and other technology advancements have resulted in more-capable, lower-cost instruments. These advances include inexpensive, high capacity recorders; fast, inexpensive, small microprocessors; and high-performance, miniaturized inertial measurement units. Additionally, the reduction in usable radio frequency spectrum has necessitated the ability to conduct test and training missions with advanced state-of-the-art, spectrally-efficient datalinks. Consequently, test and training

instrumentation systems now are amazingly similar. Functionally, both employ a two-way datalink, a GPS/IMU TSPI system, an encryptor, a high capacity recorder, and one or two microprocessors. In fact, as previously mentioned, the P5CTS datalink actually is a derivative of the ARDS datalink developed by the test community. This begs the question, "Then why are the two systems not the same?" They should be.

Both communities are likely to use the same onboard GPS and IMU hardware. Performance enhancement is achieved by employing a network of ground-based reference receivers and software modifications to accept differential corrections (via the datalink) and using Kinematic-like software algorithms. The key point is that the added performance demanded by testers is achieved with minimal, if any, cost impact on airborne instrumentation; hence, there would be no cost impact on trainers if they did not desire higher accuracy. It should be noted, however, that no-drop bomb scoring and missile fly-out simulations could benefit from higher accuracy TSPI.

Both communities need state-of-the-art embedded processing resources. It is clear that if ever commonality is to occur, sufficient processing horsepower must be made available to support both domains. Ten years ago, this may have been a true technological barrier; however, with the advent of unprecedented, affordable processing capabilities in smaller packages, and the need for operationally realistic, net-centric operational events, *both domains are faced with increased processing needs that can be met with common embedded processing*.

Both communities see multiple levels of security as essential to their TSPI instrumentation needs. Given the drive for greater coalition-based warfare and related exercises, trainers have pointed to the need for some form of multilevel security. Net-centricity demands that testers also evaluate systems in a coalition warfare-based environment, again supporting *a common multilevel security architecture*. (Based on current technology, it is becoming increasingly evident that achievable multilevel security lies in the Multiple Independent Levels of Security architecture, in which independent participants process all data at their personal level of encryption, while data blending is created via post-processing using a cross-domain solution to share data at appropriate classification levels.)

Both communities require similar datalink properties, especially regarding operational range, flexibility, and reprogrammability. Testers and trainers both employ a two-way datalink that operates in the L-band (1–2 GHz); the primary purpose of these datalinks is to pass TSPI data. Moreover, both communities are developing Joint Tactical Radio System (JTRS)–compliant waveforms, the training version of which is referred to as the Range Instrumentation Waveform (RIW). It is true that testing and training operate at different frequencies in the L-band and that the new waveforms will employ different access schemes. Typically, periodic messaging for testers will be implemented with time-slotted network access schemes, referred to as time division multiple access, whereas a periodic messaging for trainers will be implemented with signal collision avoidance network access schemes. *Nevertheless, with today's technology, it is straightforward to either:*

- *Build a radio that operates over both test and training radio bands and supports software versions of both community waveforms, or*
- *Develop a waveform that supports the needs of both communities.*

Given that requirements of testers and trainers can be met with very similar technologies, is there a system that can meet the needs of both communities?

The answer is yes.

CRIIS: A standards-based approach capable of meeting the requirements for both test and training

The Test Resource Management Center is funding the next generation GPS-based TSPI system, referred to as CRIIS, which incorporates a standards-based approach in the development of the system architecture *(Figure 1)*. This approach is being used in a number of areas, including incorporation of Test and Training Enabling Architecture (TENA) interfaces and the development of a JTRS-compliant radio. Internal standards are being developed to implement a modular, open architecture design, with Multiple Independent Levels of Security as an essential architectural element. Moreover, components will be miniaturized to help facilitate the placement of instrumentation inside space-limited vehicles.

CRIIS capabilities trace back to requirements developed and honed by the test community during the last 20 years and incorporated in the CRIIS Test Capabilities Requirement Document. In addition to meeting the needs of testers, the CRIIS Program Office has worked with training community representatives to compare, line-by-line, the P5CTS Operational Requirements Document and the CRIIS Test Capabilities Requirement Document to ensure that the CRIIS design can accommodate the needs of the training community. Not surprisingly, the result is that

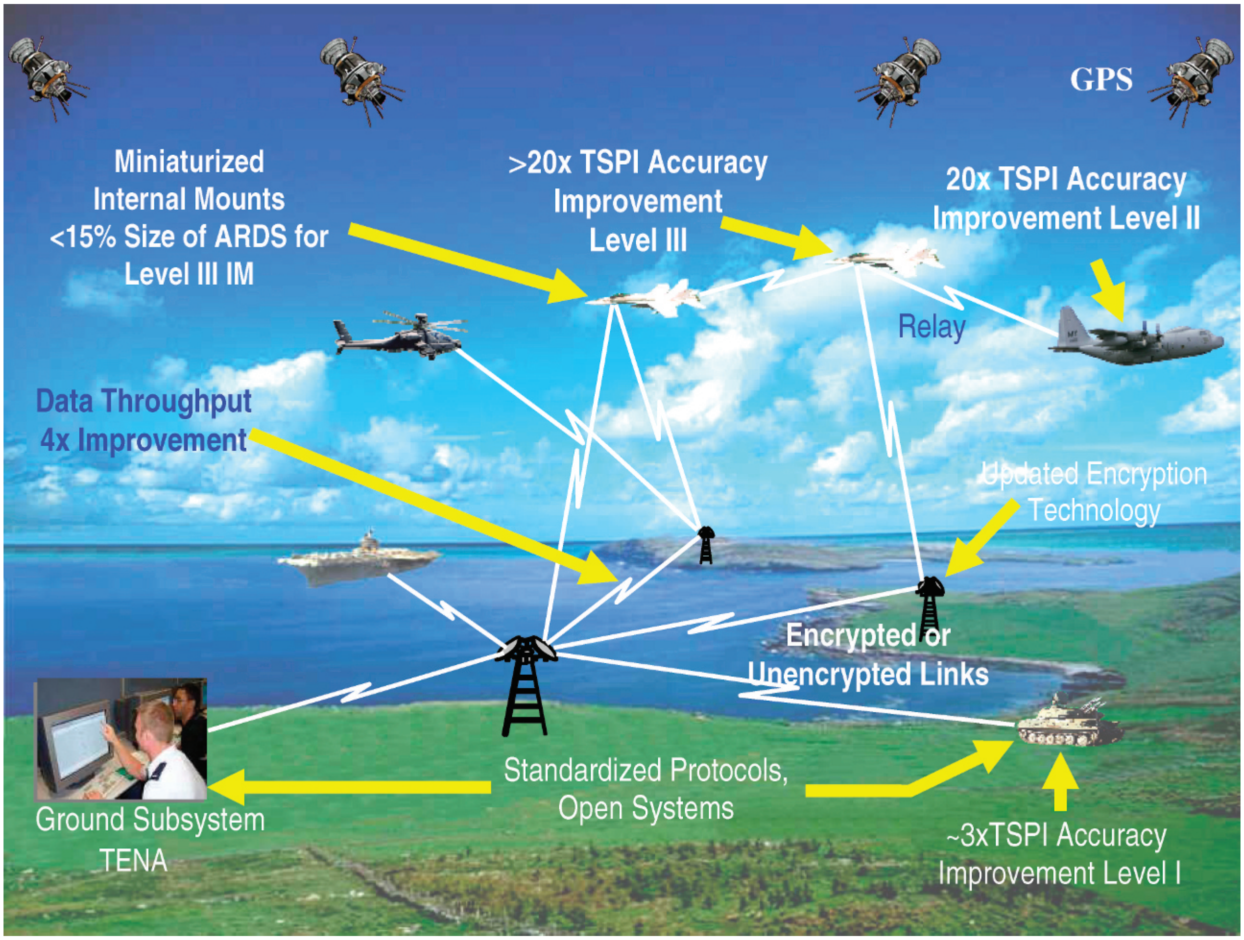

Figure 1. CRIIS Concept of Operations.

all but a few requirements are common to both communities; those that are not common can easily be engineered into the system for domain-unique application.

The major features of CRIIS include the following:

- A 20-fold improvement in TSPI accuracy by employing kinematic-type processing; the resultant submeter-accuracy will ensure that CRIIS remains a valid truth source for many years to come.
- A fourfold enhancement in datalink throughput; this is required to support a greater number of test participants, higher update rates, and greater accuracy.
- A radio compliant with software communications architecture that will employ spectrum efficient modulation; the software communications architecture will facilitate running other JTRS-compliant waveforms, such as RIW.
- A Multiple Independent Levels of Security–based radio that greatly simplifies the ability to conduct joint test or training exercises with our allies.

CRIIS will use TENA, the fundamental data-sharing medium adopted by both test and training communities and the cornerstone of the Joint Mission Environment Test Capability. Moreover, TENA is used by the training community and by several advanced instrumentation systems being developed by the Central Test and Evaluation Investment Program, including Integrated Network Enhanced Telemetry (iNET), Interoperability Test and Evaluation Capability, and the Joint Mobile Infrared Counter Measure Test System. By using TENA for all transmission control protocol/Internet protocol data transfer, CRIIS can be integrated into existing ranges and will be able to interoperate with other TENA-compliant systems, simulations, and hardware-in-the-loop laboratories. All existing TENA-compliant range control and display systems will be able to incorporate CRIIS with minor (if any) software modifications. The use of TENA makes the deployment of CRIIS to test and training ranges much more affordable than the deployment of ARDS was in the late 1980s and early 1990s.

The CRIIS radio will comply with applicable JTRS tenets, including adherence to software communica-

Table 1. Test and training requirements addressed by CRIIS capabilities

Required capability	Tester requirement	Trainer requirement	CRIIS capability
GPS/IMU-based TSPI	High accuracy	Moderate accuracy	Meets need of both communities with no added cost to trainers
MLS	Required	Required	MILS provided
Recorders	Moderate capacity	High capacity	Provides high capacity recorder with no added cost to testers
Microprocessors	Capacity/speed driven by TSPI	Capacity/speed driven by on-board weapon simulations	Microprocessors sized to meet the needs of both communities
Two-way Datalink	-Periodic messaging -Mid L-band -JTRS waveform	-Aperiodic messaging -High L-band -JTRS waveform	JTRS compliant radio with tunable RF front-end meets needs of both communities

CRIIS, Common Range Integrated Instrumentation System; GPS/IMU, Global Positioning System/Inertial Measurement Unit; TSPI, time-space-position information; MILS, Multiple Independent Levels of Security; JTRS, Joint Tactical Radio System, RF, radio frequency.

tions architecture design requirements and incorporation of JTRS Application Programming Interfaces. The primary impetus behind this design is the desire to provide a standards-based radio that can host RIW, which originally was intended to be hosted on the JTRS Small Form Factor-K radio. Because RIW will be a training range standard for some time to come and because of the desire to support joint test and training operations, the CRIIS radio will, as a minimum, implement all Application Programming Interfaces required to run RIW. Additionally, as the CRIIS test waveform is being developed, all JTRS Application Programming Interfaces will be implemented to the extent that they are technically feasible. The resulting radio will be submitted to the JTRS Joint Program Executive Office for inclusion in the JTRS library.

Clearly, this standards-based approach, employing state-of-the-art technologies, provides a common system that can readily meet the requirements of both the test and training communities *(Table 1)*.

Cultural versus technological barriers

Because there are no insurmountable technological barriers to creating common test and training instrumentation, one inevitably questions why it does not yet exist. Here, we shift our focus to cultural differences in the test and training communities, exploring some of the key differences.

Range independence

Historically, testers envision large land- or sea-based ranges with fixed infrastructures to perform testing, whereas trainers migrate toward rangeless capabilities to facilitate training at any worldwide location. This cultural difference is sometimes used to justify different developments. The reality of this changing age is that weapons, such as small-diameter bombs, demand increased footprints beyond traditional range space; compound this with future platforms such as hypersonic vehicles and unmanned aerial vehicles and add the complexities of worldwide-distributed live, virtual, and constructive test and training, and it is evident that trainers are correct not to rely solely on traditional fixed ranges to solve future training challenges. Any new range TSPI system must support in-range and rangeless applications.

Philosophies of data link management

Some have argued that the need for aperiodic, rather than periodic, updates drives either domain to different data link architectures, in the process forever dividing the two domains; however, as we have shown, the differences are vastly overstated and can be technologically bridged within the state-of-the-art. Trainers are using the ARDS-based time division multiple access structure now and likely will continue to do so for the foreseeable future. Given enough throughput, the choke points of throughput necessary for engagement evaluations are tremendously reduced. Meanwhile, for testers in the closely related field of telemetry, work is underway on iNET, which seeks to provide the next generation of telemetry to test ranges. By adopting an Internet protocol-based approach to data collection, iNET has shifted away from absolute periodic test data, opening the door to testers living with some degree of aperiodic system-under-test updates. Thus, iNET provides the flexibility both for periodic messaging schemes (as with URITS and other current training systems) and for aperiodic messaging (as testers will with iNET). Even if both communities insist on maintaining their community-unique messaging scheme, it would not be a showstopper for achieving highly interoperable systems; conceivably, a single test and training waveform could be developed to support both communities (e.g., two modes of which half the time is devoted to periodic messaging and the other half to aperiodic messaging).

Obsolescent-driven investment

Both test and training domains are reticent to provide wholesale overhauls of their respective TSPI infrastructures, historically waiting until the brink of obsolescence to change. When this change becomes inevitable, there can be apprehension that Service leaders might delay needed production efforts to wait for the next promised technological innovation. Trainers presently completing acquisition of the P5CTS system have breathing room to consider making a technological change to an upgraded capability, whereas testers must replace the near-obsolete ARDS system with CRIIS in the near future. Thus we find ourselves in a unique situation where collaborative investment by both domains is both attainable and sensible.

Fixed philosophies, changing realities

A common mantra heard among trainers is, "If we do not need enhanced accuracy, why pay for something we do not need?" As previously discussed, the enhanced accuracy provided by CRIIS comes at *no cost* to trainers if they do not need it. The reality, though, is that every time positional accuracy improves, testers and trainers find ways to exploit it—for better weapons, better test results, and better training. Moreover, a standards-based approach enables testers to adapt individual systems for higher accuracy without requiring fleet-wide fixed investments by all users, potentially including trainers. Testers historically have envisioned isolating a single system for evaluation; however, net-centricity has made that way of thinking obsolete. Once more a common solution is both logical and readily achievable. The nexus between test and training has never been greater nor a common solution more evident.

Ideal solutions versus real budgets

Finally, any discussion of commonality for test and training systems is incomplete without consideration of fiscal realities. There is a cultural tendency for trainers to ride the bow wave of R&D investments by communities with deeper technology investment dollars. Historically though weapons R&D has yielded few turn-key solutions for either the test or training community; significant development remains to adapt weapon technology to test or training. In reality the best source of R&D for the training community has been, and continues to be, the test community.

The principle challenge of pooling R&D investment dollars for common solutions has long dogged both test and training communities. The former, though, have a decided advantage in the Central Test and Evaluation Investment Program and the Test and Evaluation/Science and Technology Program, which provide approximately $250M annually for multi-Service–related investments across the test domain; no equivalent programs exist within the training community. One solution could be the creation of a single, unified investment house to address both test and training domains across the Services, with enough investment resources to address both communities effectively and efficiently.

Summary: The time for test and training commonality is now!

The bottom line is that *no* technological hindrances are preventing the test and training communities from employing common TSPI instrumentation, and cultural differences have been mitigated with blended test and training approaches. CRIIS represents a unique opportunity to provide the most basic test and training function, TSPI, on a common platform and, in turn, to realize significant benefits for both domains.

The time to act is now! The increased benefits are evident, and a detailed cost benefit analysis conducted by the Air Force revealed a potential for an annualized savings of $14M per year across both test and training domains if we migrate to a common test and training TSPI platform. However, CRIIS will soon enter system development, and once that occurs the window of opportunity for maximum commonality will be lost. *The testing community strongly encourages our training brethren to join the CRIIS effort now.* ❑

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